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## EXCLUSIVE PRODUCTION OF $\pi^+\pi^-$ PAIRS IN PROTON-PROTON AND PROTON-ANTIPROTON COLLISIONS

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We report on a detailed investigation of four-body  $pp \rightarrow pp\pi^+\pi^-$  and  $p\bar{p} \rightarrow p\bar{p}\pi^+\pi^-$  reactions which constitute an irreducible background to three-body processes  $pp \rightarrow ppM$ , where  $M$  is a broad resonance in the  $\pi^+\pi^-$  channel, e.g.  $M = \sigma, \rho^0, f_0(980), f_2(1275), f_0(1500)$ . We include double-diffractive contribution (both pomeron and reggeon exchanges) as well as the pion-pion rescattering contributions. The first process dominates at higher energies and small pion-pion invariant masses while the second becomes important at lower energies and higher pion-pion invariant masses. We compare our results with the experimental data. We make predictions for future experiments at PANDA, RHIC, Tevatron and LHC energies. The two-dimensional distribution in rapidity space of pions ( $y_{\pi^+}, y_{\pi^-}$ ) is particularly interesting. The higher the incident energy, the higher preference for the same-hemisphere emission of pions. The processes considered constitute a sizeable contribution to the total nucleon-nucleon cross section as well as to pion inclusive cross section.

*Keywords:* Exclusive processes; Central production; Pomeron and reggeon exchanges.

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### 1. Introduction

Diffractive processes are very attractive from the general point of view of the reaction mechanism. Recently there is a growing interest in understanding exclusive three-body reactions  $pp \rightarrow ppM$  at high energies, where the resonance  $M$  is produced in the central rapidity region. These resonances are seen (or will be seen) "on" the background of a  $\pi\pi$  continuum.<sup>a</sup> For example, the two-pion background to exclusive production of  $f_0(1500)$  meson, was already discussed in<sup>1</sup>. At larger energies two-pomeron exchange mechanism dominates in central production<sup>2</sup>. In

<sup>a</sup>In generality, the resonance and continuum contributions may interfere and produce even a dip. A good example is interference  $f_0(980)$  and  $\sigma$  mesons (see<sup>3,4</sup>).

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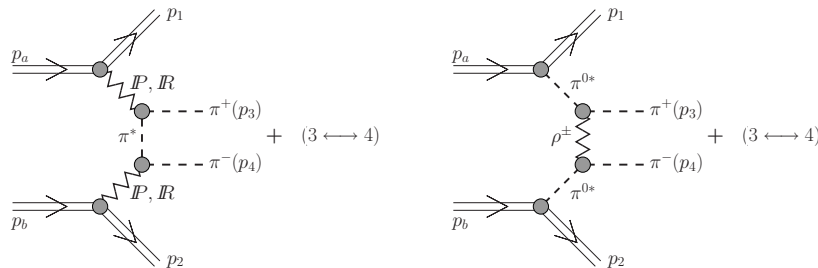


Fig. 1. Diagrams representing mechanisms for exclusive production of  $\pi^+\pi^-$  pairs at high energies. **Left:** Central double-diffractive mechanism with pomeron and reggeon exchanges. **Right:** Pion-pion rescattering mechanism (here only  $\rho$ -reggeon exchange is relevant).

calculating the amplitude related to double diffractive mechanism for  $pp \rightarrow pp\pi^+\pi^-$  we follow the general rules of Pumplin and Henyey<sup>5</sup>.

## 2. Results and Conclusions

The results presented here are based on Refs<sup>6,3</sup>, where both double diffractive and pion-pion rescattering processes were considered in detail. These mechanisms of exclusive production of  $\pi^+\pi^-$  pairs at high energies are depicted in Fig. 1.

In the first case the energy dependence of the amplitudes of  $\pi N$  subsystems was parametrized in the Regge form with pomeron and reggeon exchanges. The strength parameters and values of the pomeron and reggeon trajectories are taken from the Donnachie-Landshoff analysis<sup>7</sup> for total cross section for  $\pi N$  scattering. The slope parameters, are adjusted to the existing experimental data for elastic  $\pi N$  scattering (see details in<sup>6</sup>). There is a region of energies where the interference term dominates. We nicely describe the data for elastic  $\pi N$  scattering for  $\sqrt{s} > 2.5$  GeV.

In the second case the pion-pion amplitude was parametrized using a recent phase shift analysis at the low pion-pion energies<sup>3</sup> and a Regge form of the continuum obtained by the assumption of Regge factorization<sup>8</sup>. The two contributions occupy slightly different parts of the phase space, have different energy dependence and in principle can be resolved experimentally. The interference of amplitudes of the both processes is almost negligible.

In Fig. 2 we compare our results with experimental data for the  $pp \rightarrow pp\pi^+\pi^-$  reaction (filled circles) which are more than 1 mb for  $(2.5 < \sqrt{s} < 10)$  GeV. The integrated over full phase space cross section of the central double-diffractive component grows slowly with incident energy. At lower energies the pion-pion rescattering contributions are important, however, there the production of single and double resonances constitutes the dominant mechanism<sup>3</sup>. The search for a Double Pomeron Exchange (DPE) contribution led to an upper limits (open symbols)<sup>9</sup>.

The central double-diffractive contribution (CDD) lays along the diagonal  $y_3 = y_4$  and the classical DPE in the center  $y_3 \approx y_4$ . The  $\mathbb{P} \otimes \mathbb{P}$  cross section

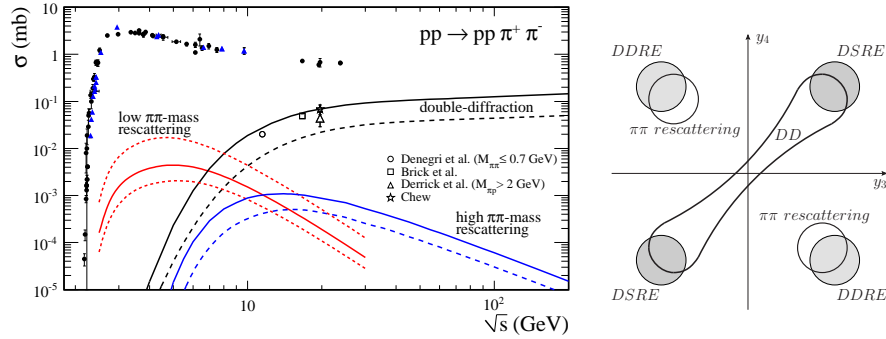
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Fig. 2. **Left:** Cross section for the  $pp \rightarrow pp\pi^+\pi^-$  reaction integrated over phase space as a function of the center-of-mass energy. We compare the pion-pion rescattering contributions obtained from partial wave analysis (low  $\pi\pi$ -mass rescattering) and from the Regge phenomenology (high  $\pi\pi$ -mass rescattering) as well as double-diffractive contribution with the experimental data. The theoretical uncertainties for these contributions are shown in addition. **Right:** A localization of different mechanisms for production of  $\pi^+\pi^-$  pairs in  $pp$  and  $p\bar{p}$  collisions at high energies.

peaks at midrapidities of pions, while  $\mathcal{P} \otimes \mathcal{R}$  and  $\mathcal{R} \otimes \mathcal{P}$  at backward and forward pion rapidities, respectively. When interfering the three components in the amplitude produce (camel-like) enhancements of the cross section at forward/backward rapidities. The diffractive single resonance excitation (DSRE) contribution is situated at the end points of the CDD contribution. The diffractive double resonance excitation (DDRE) contribution is expected at  $(y_3 \sim y_{beam}$  and  $y_4 \sim y_{target})$  or  $(y_3 \sim y_{target}$  and  $y_4 \sim y_{beam})$ , i.e. well separated from the CDD contribution.

The exciting experimental possibility of using the STAR detector at RHIC have been presented at this workshop in the plenary talk<sup>10</sup>. The future physics program of Central Production will focus on particle production resulting from the DPE process.

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